LIBERTY PAPER SET

STD. 12 : Physics

Full Solution

Time : 3 Hours **ASSIGNMENT PAPER 14**

Section A

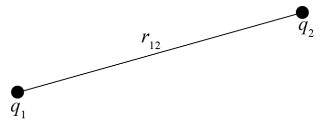
1. (A) **2.** (A) **3.** (C) **4.** (D) **5.** (A) **6.** (B) **7.** (B) **8.** (D) **9.** (C) **10.** (D) **11.** (D) **12.** (C) **13.** (C) **14.** (A) **15.** (D) **16.** (A) **17.** (C) **18.** (B) **19.** (D) **20.** (D) **21.** (D) **22.** (A) **23.** (B) **24.** (D) **25.** (A) **26.** (A) **27.** (C) **28.** (A) **29.** (C) **30.** (A) **31.** (C) **32.** (D) **33.** (C) **34.** (D) **35.** (C) **36.** (C) **37.** (D) **38.** (B) **39.** (A) **40.** (D) **41.** (A) **42.** (D) **43.** (D) **44.** (C) **45.** (B) **46.** (D) **47.** (C) **48.** (A) **49.** (D) **50.** (B)

Section A

➢ **Write the answer of the following questions : (Each carries 2 Mark)**

1.

➥ Suppose, two charges q_1 and q_2 are at initially at infinity.



➥ In the absence of external electric field work done in bringing charge q_1 from infinity to a point having position vector $\vec{r_1}$ is zero.

➥ Electric potential in the space at point P due to charge q_1

$$V_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_{1p}}$$

➥ Where, r_{1p} = distance from charge q_1 to point P.

➥ From the definition of electric potential. In the presence of electric field, work done in brining charge q_2 from infinity to the point having position vector $\vec{r_2}$,

W = (Charge q_2) × (Electric potential at distance r_{12} due to q_1)

$$W = q_2 \left(\frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_{12}} \right)$$

Where, r_{12} = distance between point 1 and 2

$$\therefore W = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r_{12}}$$

➥ This work is stored in the form of potential energy of the system. So, the potential energy of the system of the two charges,

$$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r_{12}}$$

➥ This equation is true for any signs of charges q_1 and q_2 (positive as well as negative charges).

➥ If $q_1 q_2 > 0$, the potential energy is positive. which means work done on the electric charge is positive.

➥ If $q_1 q_2 < 0$, the potential energy is negative, which means the work required to be done on electric charge is negative.

2.

➥ $C_1 = 2$ pF

$C_2 = 3$ pF

$C_3 = 4$ pF

(a) Equivalent capacitance of combination.

$C = C_1 + C_2 + C_3$

$C = 2 + 3 + 4$

$C = 9$ pF

Now, because of parallel connection, the voltages across capacitors will be 100 V here.

➥ Charge on capacitor C_1

$q_1 = C_1 V$

$= 2 \times 10^{-12} \times 100$

$= 2 \times 10^{-10}$ C

➥ Similarly, charge on capacitor C_2

$_2 = C_2V$

$= 3 \times 10^{-12} \times 100$

$= 3 \times 10^{-10}$ C

➥ The charge on capacitor C_3

$q_3 = C_3V$

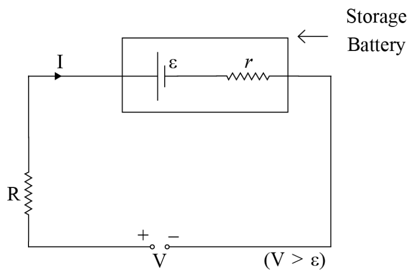
$= 4 \times 10^{-12} \times 100$

$= 4 \times 10^{-10}$ C

3.

➥ $\varepsilon = 8$ V $r = 0.5\ \Omega$

V = 120 V R = 15.5 Ω



(Battery in charging condition)

➥ The current flowing through the circuit when the battery is being charged is called the charging current.

$\therefore$ Charging current $I = \dfrac{V - \varepsilon}{R + r}$

$\therefore I = \dfrac{120 - 8}{15.5 + 0.5}$

$\therefore I = \dfrac{112}{16}$

$\therefore I = 7$ A

➥ The terminal voltage of battery during its charging,

$V' = \varepsilon - (-I)r$

$\therefore V' = \varepsilon + Ir$

$= 8 + (7)(0.5)$

$= 8 + 3.5$

$= 11.5$ V

➥ The series resistor controls the current drawn from the external DC supply. By controlling charging current, heat energy loss can be reduced.

4.

➥ $m = 0.32$ J/T

B = 0.15T

(a) Stable equilibrium condition :

➠ When the magnetic dipole moment is aligned to the external magnetic field ($\theta = 0$), the magnet is said to be in stable equilibrium.

➠ Potential energy (P.E.) of magnet in this condition,

$U = -mB\cos\theta$

$\therefore U = -(0.32)(0.15)\cos 0$

$\therefore U = -0.048$ J

(b) Unstable equilibrium condition :

➠ When the magnetic dipole moment and external magnetic field are anti parallel ($\theta = \pi$ rad), the magnet is said to be in unstable equilibrium condition.

➡ P.E. of magnet in this condition,

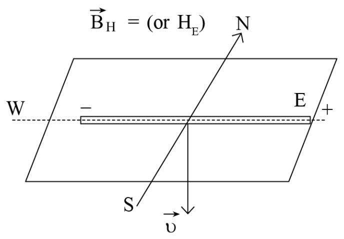
$U = -mB\cos\theta$

$\therefore U = -(0.32)(0.15)\cos\pi$

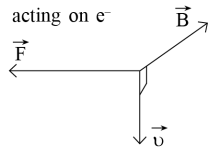
$\therefore U = -0.048(-1)$

$\therefore U = 0.048$ J

5.

➥ 

Direction of force acting on e^-



➥ $l = 10$ m

$\upsilon = 5.0$ m/sec

$B_H = 0.30 \times 10^{-4}$ T

(a) Induced *emf* in rod

$\varepsilon = B_H \upsilon l$

$= 0.30 \times 10^{-4} \times 5 \times 10$

$= 15 \times 10^{-4}$ V

$= 1.5$ mV

(b) *emf* is induced in wire in such a direction that it opposes its (wire's) motion. Thus, direction of *emf* is from West to East.

(c) When the wire is in free fall a free electron in the wire experiences a force according to the formula $\vec{F} = -e(\vec{\upsilon} \times \vec{B})$.

➡ From Fleming's left-hand rule of thumb the direction of this force is taken to mean that the force on the electron is towards, the west end of the wire.

➡ Thus the free electrons of the wire accumulate at the west end, there by exposing the east end of the wire to a positive charge.

➡ Thus the eastern end of the string is in a high potential.

6.

➥ (1) The flux leakage : There is always some flux leakage. i.e. not all the flux due to primary passes through the secondary. (due to poor design of the core or the air gaps in the core).

➡ Sol. : It can be reduced by winding the primary & secondary coils one over the other.

➥ (2) Resistance of the windings : The wire used for the windings has some resistance and so, energy is lost due to heat produced in the wire (I^2R).

➡ Sol. : This can be minimized by using thick wire in high current, low voltage windings.

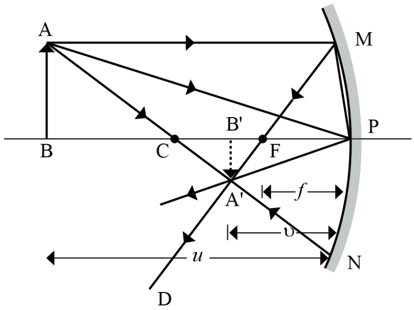
➥ (3) Eddy currents : The alternating magnetic flux induces eddy currents in the iron core and causes heating.

➡ Sol. : The effect can be reduced by housing a laminated core.

➥ (4) Hysterisis : The magnetisation of the core is repeatedly reversed by the alternating magnetic field. The resulting expenditure of energy in the core appears as heat.

➠ Sol. : Can be reduced by using a magnetic material which has low hysterisis loss.

7.

➥ 

➥ A mirror with small aperture is shown in figure. An object AB is placed in front of the mirror at some distance from the centre of curvature.

➥ Three rays emanating from A are reflected by a mirror and converge at point A'. So the image of the object AB is given by A'B' between C and F.

➥ From figure the two right-angled triangles ΔA'B'F and ΔMPF are similar. (For paraxial rays, MP can be considered to be a straight line perpendicular to CP.)

➥ Therefore, $\frac{A'B'}{MP} = \frac{B'F}{FP}$

But, AB = MP

$\frac{A'B'}{AB} = \frac{B'F}{FP}$ ... (1)

➥ The right angled triangles ΔABP and ΔA'B'P are similar.

Therefore, $\frac{A'B'}{AB} = \frac{B'P}{BP}$ ... (2)

➥ Comparing equations (1) and (2),

We get,

$\therefore \frac{B'F}{FP} = \frac{B'P}{BP}$

But, B'F = PB' – FP

$\therefore \frac{PB' - FP}{FP} = \frac{B'P}{BP}$ ... (3)

➥ But, B'P = –υ, FP = –*f*, BP = – *u*

(according to sign convention all three have negative signs)

➥ using these in equation (3), we get

$\frac{-\upsilon + f}{-f} = \frac{-\upsilon}{-u}$

$\therefore \frac{-\upsilon}{-f} - \frac{f}{f} = \frac{\upsilon}{u}$

$\therefore \frac{\upsilon}{f} - 1 = \frac{\upsilon}{u}$

➥ Now dividing by υ,

$\therefore \frac{\upsilon}{f\upsilon} - \frac{1}{\upsilon} = \frac{\upsilon}{u\upsilon}$

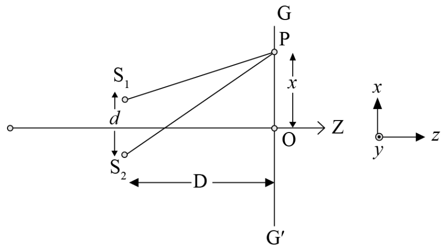
$\therefore \frac{1}{f} - \frac{1}{\upsilon} = \frac{1}{u}$

$\therefore \frac{1}{f} = \frac{1}{\upsilon} + \frac{1}{u}$

➥ It is called mirror equation.

8.

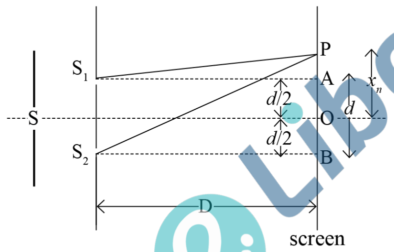
- The British physicist Thomas Young used an ingenious technique to “lock” the phases of the waves emanating from S_1 and S_2.
- He made two pinholes S_1 and S_2 (very close to each other) on an opaque screen. (fig. (a))
- These were illuminated by another pinholes that was in turn, lit by a bright source.



(b)

- Light waves spread out from S and fall on both S_1 and S_2.
- S_1 and S_2 then behave like two Coherent Sources because light waves coming out from S_1 and S_2 are derived out from same original source and any abrupt phase change in S will manifest in exactly similar phase changes in the light coming out from S_1 and S_2.
- Thus, the two sources S_1 and S_2 will be locked in phase; i.e. they will be coherent
- Thus spherical waves emanating from S_1 and S_2 will produce interference fringes on the screen GG ‘; as shown in fig. (b)

Formula derivation for fringe width and distance of n^{th} bright fringe



The dark and bright bands appear on the screen are called fringes.

The distance between two consecutive bright fringes or two consecutive dark fringes is called the fringe width.

From the triangle S_1AP

$$S_1P^2 - S_1A^2 + AP^2$$

That is

$$S_1P^2 = D^2 + [x_n - d/2]^2 \qquad ...(1)$$

From triangle S_2BP

$$S_2P^2 = S_2B^2 + BP^2$$

That is $S_2P^2 = D^2 + [x_n - d/2]^2$ ...(2)

Subtracting equation 1 from 2, we get

$$S_2P^2 - S_1P^2 = \left[x_n + \frac{d}{2}\right]^2 - \left[x_n - \frac{d}{2}\right]^2$$

$$= \left[x_n^2 + 2x_n\frac{d}{2} + d^2/4\right] - \left[x_n^2 + 2x_n\frac{d}{2} - d^2/4\right]$$

Thus, $S_2P^2 - S_1P^2 = 2dx_n$

Or

$$[S_2P - S_1P]\,[S_2P + S_1P] - 2dx_n \quad ...(3)$$

If the point P is near to O, then

$$S_2P \approx S_1P \approx D$$

Therefore, $[S_2P - S_1P]2D = 2dx_n$

Or

$$S_2P - S_1P = \frac{dx_n}{D}$$

Thus, Path Difference $= \frac{x_n d}{D}$

For the point P to be bright, the path difference = $n\lambda$, thus

$$\frac{x_n d}{D} = n\lambda$$

Therefore, the distance to n^{th} band (fringe) is

$$x_n = \frac{n\lambda D}{d};\ n = 0, \pm 1, \pm 2, ...$$

Thus, distance to $(n + 1)^{th}$ band is

$$x_{n+1} = \frac{(n+1)\lambda D}{d}$$

The band width is given by

$$\beta = x_{(n+1)} - x_n$$

Thus, $\beta = \frac{\lambda D}{d}$

This is the combined width of a dark band and a bright band.

The dark and bright bands are equally spaced.

If P is dark then,

$$x_n = \left(n + \tfrac{1}{2}\right)\frac{\lambda D}{d};\ n = 0, \pm 1, \pm 2$$

9.

- The phenomena of interference, diffraction and polarisation have proved that light has a wave nature. According to this, light is a electromagnetic wave consisting of electric and magnetic fields with continuous distribution of energy over the region of space over which the wave is extended.
- According to wave theory the intensity of light is proportional to the square of the amplitude of the light. ($I \propto A^2$)
- Thus, the energy of light is directly related to its intensity i.e. light with higher intensity has more energy, therefore, the maximum energy of the emitted electrons is also higher when the high intensity light falls on the metal surface.
- Thus, according to wave theory the energy of the photoelectron emitted from the metal depends on the intensity of light, which is the opposite from the experimental result.
- According to wave theory if the surface of a metal is exposed to light of sufficient intensity such that the energy received by the electron is greater than the work function of the metal, then electrons will be emitted regardless of the frequency of the light.
- This explanation takes out the presence of a threshold frequency inferred from experimental results.
- According to wave theory light has a continuous distribution of energy as a wave-front so when light is incident on a metal surface the energy absorbed by the electrons is also continuously absorbed by the wave front of the light.
- The number of electrons in a metal is very high, so the energy absorbed by each electron per unit time will be very small.
- Thus, the electron will absorb a very small amount of energy from the light every second and when it becomes equal to the work function, the electron will be emitted. A precise calculation shows that it should take hours for the electrons to be emitted.

➥ This explanation is also contrary to the phenomenon of spontaneous emission of electrons found by experimental results.

➥ From this it can be said that the wave theory fails to explain the photoelectric effect.

10.

➥ The limitations of the Bohr model are as follows.

➥ (i) The Bohr model is applicable to hydrogenic atoms. It cannot be extended even to more two electron atoms such as helium.

➠ The analysis of atoms with more than one electron was attempted on the lines of Bohr's model for hydrogenic atoms but did not meet with any success. Because the electron interacts not only with the positively charged nucleus but also with all other electrons.

➥ (ii) The Bohr's model correctly predicts the frequencies of the light emitted by hydrogenic atoms. However, the model cannot explain the relative intensities of the frequencies in the spectrum.

➠ In emission spectrum of hydrogen, some of the visible frequencies have weak intensity, others strong which cannot be explained by Bohr's model.

➠ Experimental observation show that some transitions are more favoured than others. Bohr's model is unable to account for the intensity variation.

11.

➥ Nucleus contains protons and neutrons, in which there is a coulomb repulsion between protons and protons. However, the proton can not escape from the nucleus. Because to bind a nucleus together there must be a strong attractive force of a totally different kind. It must be strong enough to overcome the repulsion between (the positively charged) protons and to bind both protons and neutrons into the tiny nuclear volume.

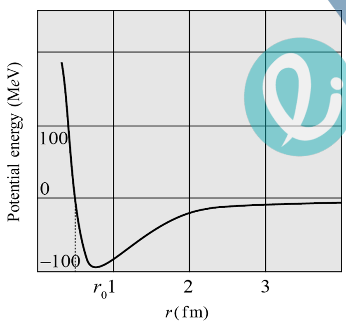
➥ Many features of the nuclear binding force are summarised below :

(i) The nuclear force is much stronger than the Coulomb force acting between charges or the gravitational forces between masses. That's why it holds protons and neutrons in the nucleus.

(ii) The range of the nuclear force is of the order of femtometres. For distances greater than one femtometres this force rapidly decreases to zero.

➠ This leads to saturation of forces in a medium or a large sized nucleus.

➠ A plot of the potential energy between two nucleons as a function of distance as shown in figure.



➠ The potential energy is minimum at a distance r_0 of about 0.8 fm. The force is attractive for distance larger than 0.8 fm.

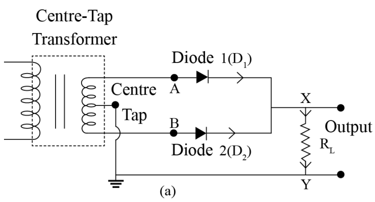
➠ The force is repulsive for distance less than 0.8 fm.

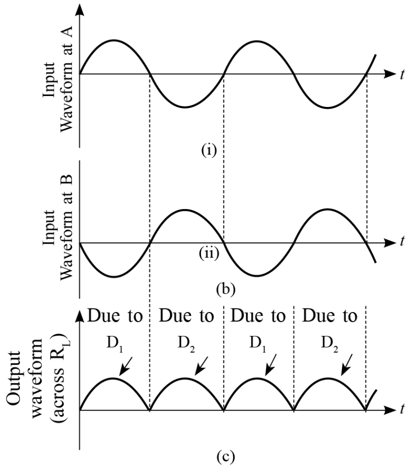
(iii) The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.

➠ Unlike Coulomb's law or the Newton's law of gravitation there is no simple mathematical form of the nuclear force.

12.

➥





- The circuit diagram of the full-wave rectifier is shown in the figure. In full wave rectifier, two *p - n* junction diodes are used.
- In this type of rectifier, the rectified output voltage is obtained during both the positive as well as negative half of ac cycle. Hence, it is known as full-wave rectifier.
- As shown in fig., the *p*-side of the two diodes are connected to the ends of the secondary of the transformer. The *n*-side of the diodes are connected together and the output is taken between this common point of diodes and the mid-point of the secondary of the transformer. So for a full wave rectifier the secondary of the transformer is provided with a centre tapping and so it is called centre-tap transformer.
- As can be seen from fig. (c), the voltage rectified by each diode is only half the total secondary voltage. Each diode rectifies only for half the cycle, but the two do so for alternate cycles. Thus the output between their common terminals and the centre tap of the transformer becomes a full-wave rectifier output.
- Suppose the input voltage to A with respect to centre tap at any instant is positive. At that instant, voltage B being out of phase should be negative. In this case, diode D_1 gets forward biased and conducts, while D_2 gets reverse biased and does not conduct. Hence, as shown in fig. c, output current is obtained between two terminals of R_L during this half-cycle.
- During the other half-cycle, voltage at A is negative and voltage at B is positive. In this case diode D_1 is in reverse bias condition and D_2 is in forward bias. Hence, in this part of cycle, D_2 conducts and output voltage is obtained.
- Thus, we get output voltage during both positive as well as negative half of the cycle.

Section B

➢ **Write the answer of the following questions : (Each carries 3 Mark)**

13.

- (a) $Q = 4 \times 10^{-7}$ C

  $r = 9\ cm$

  - Potential at point P

    $$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r}$$

    $$\therefore V = \frac{9 \times 10^9 \times 4 \times 10^{-7}}{9 \times 10^{-2}}$$

    $$\therefore V = 4 \times 10^4\ V$$

- (b) Work done in bringing charge

  $q = 2 \times 10^{-9}$ C

  at Point P,

  $W = Vq$

  $\therefore W = 4 \times 10^4 \times 2 \times 10^{-9}$

$\therefore W = 8 \times 10^{-5}$ J

➥ Here work done is independent of path.

14.

➥ $q_A = 2 \propto C$ $q_B = -5 \propto C$ $q = 1 \propto C$

$q_C = 2 \propto C$ $q_D = -5 \propto C$ $l = 10$ cm

➥ Suppose, the distance from the centre of square to any one of the vertices is 'r'.

$\therefore$ AO = BO = CO = DO

$$r = \frac{\sqrt{(10)^2 + (10)^2}}{2} = 5\sqrt{2}\ \text{cm} = 5\sqrt{2} \cdot 10^{-2}\ \text{m}$$

➥ Force exerted on $q = 1 \propto C$ charge on point 'O' due to the charge $q_A = 2 \propto C$ on A,

$$F_A = \frac{kq_A q}{r^2} = \frac{9 \times 10^9 \times 2 \times 10^{-6} \times 1 \times 10^{-6}}{\left(5\sqrt{2} \times 10^{-2}\right)^2}$$

$\therefore F_A = 3.6$ N ... (1) (From A to O direction)

➥ Similarly, force exerted on $q = 1 \propto C$ charge on point 'O' due to the charge $q_C = 2 \propto C$ On C,

$$F_C = \frac{kq_C q}{r^2} = \frac{9 \times 10^9 \times 2 \times 10^{-6} \times 1 \times 10^{-6}}{\left(5\sqrt{2} \times 10^{-2}\right)^2}$$

$\therefore F_C = 3.6$ N ... (2) (From C to O direction)

From eq. (1) and (2),

➥ Forces F_A and F_C are equal in magnitude and in opposite directions, So their net force will be zero.

$$\vec{F_1} = \vec{F_A} + \vec{F_C} = \vec{0}$$

➥ Force exerted on $q = 1 \propto C$ charge on point 'O' due to the charge $q_B = -5 \propto C$ on 'B',

$$F_B = \frac{kq_B q}{r^2} = \frac{9 \times 10^9 \times 5 \times 10^{-6} \times 1 \times 10^{-6}}{\left(5\sqrt{2} \times 10^{-2}\right)^2} = 9\ \text{N ... (3) (From O to B direction)}$$

➥ Similarly, the force exerted on $q = 1 \propto C$ at centre, due to the charge on point D,

$$F_D = \frac{kq_D q}{r^2} = \frac{9 \times 10^9 \times 5 \times 10^{-6} \times 1 \times 10^{-6}}{\left(5\sqrt{2} \times 10^{-2}\right)^2}$$

$\therefore F_D = 9$ N ... (4) (From O to D direction)

➥ From eq. (3) and (4), F_B and F_D both forces are of equal magnitude and opposite dirction, So, their resultant (Net) force is zero.

$$\therefore \vec{F_2} = \vec{F_B} + \vec{F_D} = \vec{0}$$

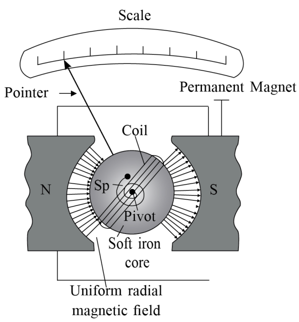
➥ $\therefore$ The net force acting on the electric charge on point 'O',

$$\vec{F} = \vec{F_1} + \vec{F_2} = \vec{0} + \vec{0} = \vec{0}$$

$$\therefore \vec{F} = \vec{0}$$

15.

➥



- Figure shows a moving coil galvanometer.
- Principle :
- A torque is exerted on the current carrying coil placed in uniform magnetic field.
- Construction :
- A thin copper wire is wounded on rectangular frame placed between two cylindrical permanent magnets as shown in the figure. The coil is arranged so it can rotate freely.
- A small cylinder of soft iron is placed on the axis of the coil, without touching the coil, to produce a uniform radial magnetic field.
- When current is passed through the coil a torque acts on it and it deflects. The steady deflection of coil is indicated by a pointer attached with it.
- Working :
- When a current flows through the coil, a torque acts on it, causing it to deflect.
- If the area vector of the coil makes an angle θ with the magnetic field, torque acting on coil is

  $\tau = \text{NIBA}\, sin\, \theta$
- Due to the radial magnetic field, the angle between $\vec{A}$ and $\vec{B}$ will always be 90°.

  $\therefore\ \tau = \text{NIBA}$ ...(1)
- Due to the deflection of the coil, the restoring torque is produced in the spring which is directly proportional to the deflection of the coil (φ)

  $\therefore$ Restoring torque $\tau' = k\,\varphi$ ...(2)

  Where, k = torsional constant of the spring.
- For steady deflection, from equation (1) & (2)

  $\tau' = \tau$

  $k\varphi = \text{NIAB}$

  $\therefore \varphi = \left(\frac{\text{BAN}}{k}\right) \cdot \text{I}$

  $\therefore \varphi \propto \text{I}$ ($\because$ B, A, N, K are constant) ...(3)
- Thus, the deflection of the coil is directly proportional to the current.
- Uses : Galvanometer is used to detect the presence of current in the circuit.
- To measure small electric currents (of the order 10^{-6} A)
- Using galvanometer, ammeter and voltmeter can be constructed.

16.

- n = Number of turns per unit length

  $n = 15\ \frac{\text{turns}}{\text{cm}}$

  $= 1500\ \frac{\text{turns}}{\text{m}}$
- $\text{A} = 2\ \text{cm}^2$

  $= 2 \times 10^{-4}\ \text{m}^2$

  $\text{I}_1 = 2\text{A}$

  $\text{I}_2 = 4\text{A}$

  $\Delta t = 0.1$ sec
- Induced *emf*

  $|\varepsilon| = \frac{\Delta\phi}{\Delta t}$

  $\therefore |\varepsilon| = \frac{\phi_2 - \phi_1}{\Delta t}$

  $\therefore |\varepsilon| = \frac{\text{B}_2\text{A} - \text{B}_1\text{A}}{\Delta \text{t}}$

$$\therefore |\varepsilon| = \frac{\mu_0 n I_2 A - \mu_0 n I_1 A}{\Delta t}$$

$$\therefore |\varepsilon| = \frac{\mu_0 n A (I_2 - I_1)}{\Delta t}$$

$$\therefore |\varepsilon| = \frac{4\pi \times 10^{-7} \times 1500 \times 2 \times 10^{-4} (4-2)}{0.1}$$

$$\therefore |\varepsilon| = 753600 \times 10^{-11}$$

$$\therefore |\varepsilon| = 7.54 \times 10^{-6} \text{ V}$$

$$\therefore |\varepsilon| = 7.54 \propto \text{V}$$

17.

- $V = 220$ V

  $\nu = 50$ Hz

  $R = 200\ \Omega$

  $C = 15\ \mu F$

- Capacitive reactance,

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi \nu C}$$

$$= \frac{1}{2 \times 3.14 \times 50 \times 15 \times 10^{-6}}$$

$$X_C = 212.3\ \Omega$$

- (a) Impedence of the circuit,

$$Z = \sqrt{R^2 + X_C^{\ 2}}$$

$$\therefore Z = \sqrt{(200)^2 + (212.3)^2}$$

$$\therefore Z = \sqrt{40000 + 45071.29}$$

$$\therefore Z = \sqrt{85071.29}$$

$$\therefore Z = 291.67\ \Omega$$

- Electric current in the circuit,

$$\therefore I = \frac{V}{Z}$$

$$= \frac{220}{291.67}$$

$$\therefore I = 0.7542 \text{ A}$$

(b) Voltage across two terminals of resistor (V_R),

$$V_R = IR$$

$$= (0.754)(200)$$

$$= 150.8 \text{ V}$$

- Voltage across two terminals of capacitor (V_C)

$$V_C = I X_C$$

$$= (0.754)(212.3)$$

$$= 160.07 \text{ V}$$

- Algebric sum of V_R and V_C,

$$V' = V_R + V_C$$

$$V' = 150.8 + 160.07$$

$$V' = 310.87 \text{ V}$$

- which is more than the source voltage V = 220 V.
- Here, both the voltages V_R and V_C are not in same phase, hence they can not be added like normal numbers, directly.
- But the phase-difference between V_R and V_C is 90°. So, from Phythagoras theorem,

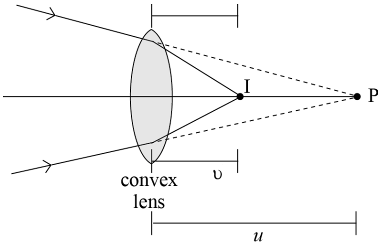
Total voltage $V_{R+C} = \sqrt{V_R^2 + V_C^2}$

$$V_{R+C} \approx 220 \text{ V}$$

- Thus, if the phase difference between the two voltages is taken in to consideration and calculation is done appropriately, the total voltage between two terminals of capacitor and resistor is found to be same as the source voltage.

18.

➥ (a) for convex lens,



➠ As shown in the figure, placing a convex lens in the path of a beam of light, it concentrates at point I. (∵ it is converging lens.)

➠ Here the point P behaves as a virtual object.

∴ object-distance u = 12 cm

image-distance υ = ?

focal length f = 20 cm

➠ from lens formula,

$$\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$$

$$\therefore \frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$$

$$\therefore \frac{1}{\upsilon} = \frac{1}{20} + \frac{1}{12}$$

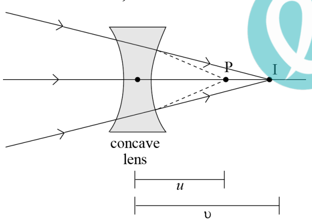
$$\therefore \frac{1}{\upsilon} = \frac{3+5}{60}$$

$$\therefore \upsilon = \frac{60}{8}$$

= 7.5 cm

➠ This beam of light is concentrated near point I at a distance of 7.5 cm as shown in figure.

➥ (b) for concave lens,



➠ As shown in figure, placing a concave lens in the path of a beam of light is concentrated near I.

∴ object distance u = 12 cm

image distance υ = ?

focal length f = –16 cm

➠ from lens formula,

$$\frac{1}{\upsilon} - \frac{1}{u} = \frac{1}{f}$$

$$\therefore \frac{1}{\upsilon} = \frac{1}{f} + \frac{1}{u}$$

$$\therefore \frac{1}{\upsilon} = \frac{-1}{16} + \frac{1}{12}$$

$$\therefore \frac{1}{\upsilon} = \frac{-3+4}{48}$$

∴ υ = 48 cm

➠ This beam of light is concentrated near point I at a distance of 48 cm as shown in figure.

19.

- The light emitted from an oridinary source (like a sodium lamp) is unpolarised.
- When such a light is passed through a polaroid sheet P_1, it is observed that its intensity is reduced by half. Rotating P_1 has no effect on the transmitted beam and transmitted intensity remains constant.
- Now, let an identical piece of polaroid P_2 be placed before P_1.
- As shown in Fig., initially P_1 and P_2 are arranged in such a way that their pass-axis are parallel to each other.
- In this case, the intensity of the transmitted light is the same.
- Now, if P_1 is rotated, there is variation seen in the light coming out of P_2.
- As shown in a position in the fig., the intensity transmitted through P_2 followed by P_1 is nearly zero.
- When P_1 is rotated by 90°, in one position for light coming from P_2, total intensity is absorbed by P_1. So, the intensity of light emerging from P_1 is zero.
- Suppose, the pass axis of P_2 makes an angle θ with the pass axis of P_1, then when the polarised beam passes through the polaroid P_2, the component $E\cos\theta$ (along the pass-axis of P_2) will pass through P_2. Thus, as we rotate the polaroid P_1 (or P_2), the intensity will vary as :

  $I = I_0 \cos^2\theta$

  where I_0 is the intensity of the polarized light after passing through P_1.
- This is known as Malus' law.
- The above discussion shows that the intensity coming out of a single polaroid is half of the incident intensity. By putting a second polaroid, the intensity can be further controlled from 50% to zero of the incident intensity by adjusting the angle between the pass axis of two polaroids.

20.

- (a) For bullet, $m = 0.040$ kg

  $v = 1.0$ km/s $= 1 \times 10^3\ ms^{-1}$

  - The de-Broglie wavelength,

  $\lambda = \frac{h}{p} = \frac{h}{mv}$

  $\lambda = \frac{6.625 \times 10^{-34}}{0.040 \times 1 \times 10^3}$

  $\lambda = 165.625 \times 10^{-37}$

  $\lambda = 1.66 \times 10^{-35}$ m

  (b) For ball, $m = 0.060$ kg

  $v = 1$ m/s

  - The de-Broglie wavelength

  $\lambda = \frac{h}{p} = \frac{h}{mv}$

  $\lambda = \frac{6.625 \times 10^{-34}}{0.060 \times 1}$

  $\lambda = 110.416 \times 10^{-34}$

  $\lambda = 1.104 \times 10^{-32}$ m

  (c) For the dust particle,

  $m = 1 \times 10^{-9}$ kg

  $v = 2.2$ m/s

  - The de-Broglie wavelength,

  $\lambda = \frac{h}{p} = \frac{h}{mv}$

  $\lambda = \frac{6.625 \times 10^{-34}}{1 \times 10^{-9} \times 2.2}$

  $\lambda = 3.01 \times 10^{-25}$ m

21.

- Bohr's second postulate :
- An electron revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $\frac{h}{2\pi}$.

  Where, h is Planck's constant
- $h = 6.625 \times 10^{-34}$ Js
- Thus the angular momentum of the electron

  $L = \frac{nh}{2\pi}$ Where, $n = 1, 2, 3$ ......
- De - Broglie's explanation :
- According to de-Broglie's hypothesis even matter particles like electrons have wave nature. Its practical explanation was given by Davisson and Germer, from which de-Broglie argued that the electron in its circular orbit must be seen as a particle wave.
- When the tensioned wire is plucked tied to a rigid support on both ends, a vast number of wavelengths are excited. However only those wavelengths survive which have nodes at the ends and form the standing wave in the string. It means standing waves are formed when the total distance travelled by a wave down the string and back is one wavelength or any integral number of wavelength.
- Waves with other wavelengths interfere with themselves upon reflection and their amplitudes rapidly drop to zero.
- For an electron moving in n^{th} circular orbit of radius r_n, the total distance is the circumference of the orbit. Thus,

  $2\pi r_n = n\lambda$ ... (1)

  Where $n = 1, 2, 3,$ ....
- But the de-Broglie wavelength $\lambda = \frac{h}{p}$

  Where p = momentum of electron. If the speed of the electron is much less than the speed of light, the momentum is = mv_n

  $\therefore \lambda = \frac{h}{mv_n}$ ... (2)
- Form equation (1) and (2),

  $\therefore 2\pi r_n = \frac{nh}{mv_n}$

  $\therefore mv_n r_n = \frac{nh}{2\pi}$
- This is the quantum condition proposed by Bohr for the angular momentum of the electron.
- Thus, de-Broglie hypothesis provided an explanation for Bohr's second postulate for the quantisation of angular momentum of the orbiting electron.

Section C

➢ **Write the answer of the following questions : (Each carries 4 Mark)**

22.

- $A = 6 \times 10^{-3}$ m^2

  $d = 3$ mm $= 3 \times 10^{-3}$ m

  V = 100 V

  (a) Capacitance, when there is air between two plates,

  $C = \frac{\varepsilon_0 A}{d}$

$\therefore C = \frac{8.85 \times 10^{-12} \times 6 \times 10^{-3}}{3 \times 10^{-3}}$

$\therefore C \approx 18 \times 10^{-12}$

$\therefore C \approx 18$ pF

(b) Electric charge on each plate,

$q = CV$

$= 18 \times 10^{-12} \times 100$

$= 18 \times 10^{-10}$ C

$= 1.8 \times 10^{-9}$ C

$= 1.8\ n$C

➥ On one plate of capacitor there will be a positive charge 1.8 nC and on the other plate there will be a negative charge 1.8 nC

23.

➥ (a) Number of atoms per unit volume in the given copper wire,

$$n = \frac{N}{V} = \frac{N}{\left(\frac{m}{d}\right)} = \frac{N\,.\,d}{m}$$

➠ We know when $N = N_A$, the mass $m = M_0$ substituting that in above eqation

$$n = \frac{N_A\,.\,d}{M_0}$$

$N_A = 6 \times 10^{23}$, $d = 9 \times 10^3$ kg m^{-3}

$M_0 = 63.5 \times 10^{-3}$ kg ($\because M_0 = 63.5\ u = 63.5\ \frac{g}{mol}$)

$$n = \frac{6 \times 10^{23} \times 9 \times 10^3}{63.5 \times 10^{-3}} = 8.5 \times 10^{28}\ m^{-3}$$

➠ Drift speed of electron,

$I = ne\,\upsilon_d\,A$

$$\upsilon_d = \frac{I}{A\,ne}$$

$$\therefore \upsilon_d = \frac{1.5}{(1 \times 10^{-7}) \times (8.5 \times 10^{28}) \times (1.6 \times 10^{-19})}$$

$\therefore \upsilon_d = 1.1 \times 10^{-3}$ m/s

$\therefore \upsilon_d = 1.1$ mm/s

➥ (b) (i) The mass of one copper atom

$$M = \frac{M_0}{N_A} = \frac{63.5 \times 10^{-3}}{6.0 \times 10^{23}} = 1.058 \times 10^{-25}\ kg$$

➠ Thermal speed of atoms at ordinary temperature,

$\upsilon_{rms} = \sqrt{\frac{3k_B T}{M}}$ (where $k_B = 1.38 \times 10^{-23}\ \frac{J}{mol k}$ is known as Boltzmaan constant.)

$$\therefore \upsilon_{rms} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 300}{1.058 \times 10^{-25}}}$$

$\therefore \upsilon_{rms} = 3.42 \times 10^2$ m/s

➠ $$\frac{\text{Drift speed of electorn}}{\text{Thermal speed of atom}} = \frac{\upsilon_d}{\upsilon_{rms}} = \frac{1.1 \times 10^{-3}}{3.42 \times 10^2}$$

➥ $= 3.2 \times 10^{-6}$

➠ Hence, the drift speed of electrons is very small (order of $\approx 10^{-6}$) compared to the thermal speed of the atom for the same temperature.

(ii) The speed of electric field inside the conductor is same as the speed of electromagnetic wave in vacuum (c), 3×10^8 m/s

$$\therefore \frac{\text{Drift speed of electron}}{\text{Speed of electric field}} = \frac{\upsilon_d}{c} = \frac{1.1 \times 10^{-3}}{3 \times 10^8}$$

$\approx 3.7 \times 10^{-12}$

- So, the speed of electric field inside the conductor is very high as compared to the drift speed of electron.

24.

- $B = 6.5\text{ G} = 6.5 \times 10^{-4}\text{ T}$ $\upsilon = 4.8 \times 10^6\text{ m/s}^{-1}$

  $e = 1.6 \times 10^{-19}\text{ C}$ $m_e = 9.1 \times 10^{-31}\text{ kg}$

- The force on the electron due to the magnetic field is $q(\vec{\upsilon} \times \vec{B})$. The direction of this force is perpendicular to both velocity and magnetic field.
- In uniform circular motion, the velocity is tangential and the centripetal force is toward the center of the circular path. Here, velocity and force are perpendicular to each other.
- Hence, the magnetic force $e(\vec{\upsilon} \times \vec{B})$ on the electron provides a centripetal force, so that the path of the electron is circular.
- The radius of path,

$$r = \frac{m_e \upsilon}{eB} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}$$

$\therefore r = 4.2 \times 10^{-2}$ m

$\therefore r = 4.2$ cm

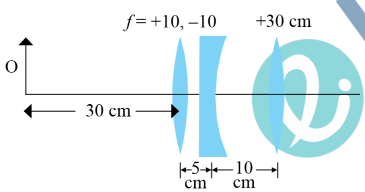
25.

- For first lens,

  $u_1 = -30$ cm

  $f = 10$ cm

  $\upsilon_1 = ?$



- From lens formula,
- For the image formed by the first lens,

$$\frac{1}{\upsilon_1} - \frac{1}{u_1} = \frac{1}{f}$$

$$\therefore \frac{1}{\upsilon_1} = \frac{1}{f} + \frac{1}{u_1}$$

$$\therefore \frac{1}{\upsilon_1} = \frac{1}{10} - \frac{1}{30}$$

$$\therefore \frac{1}{\upsilon_1} = \frac{3-1}{30}$$

$\therefore \upsilon_1 = 15$ cm

- Image formed by first lens acts as a virtual object for the second lens.
- Object distance for second lens = 15 – 5

  $u_2 = 10$ cm

  (u_2 is positive, means it is in the direction of the incident ray)

- From lens formula,

$$\frac{1}{\upsilon_2} - \frac{1}{u_2} = \frac{1}{f_2}$$

$$\therefore \frac{1}{\upsilon_2} - \frac{1}{10} = -\frac{1}{10}$$

$$\therefore \frac{1}{\upsilon_2} = 0$$

$$\therefore \upsilon_2 = \infty \text{ (infinite)}$$

- This image acts as a virtual object for the third lens. So the object distance for the third lens is infinite.
- For the third lens $u_3 = \infty$
- From lens formula,

$$\frac{1}{\upsilon_3} - \frac{1}{u_3} = \frac{1}{f_3}$$

$$\therefore \frac{1}{\upsilon_3} - \frac{1}{\infty} = \frac{1}{30}$$

$$\therefore \frac{1}{\upsilon_3} = \frac{1}{30} \left(\because \frac{1}{\infty} = 0\right)$$

$$\therefore \upsilon_3 = 30 \text{ cm}$$

- Thus, final image is formed at 30 cm distance on the right side of the third lens.

26.

- Bohr combined classical and early quantum concepts and gave his theory in the form of three postulates. These are :
- (i) Bohr's first postulate : An electron in an atom could revolve in certain stable orbits without the emission of radiant energy.
  - According to this postulate, each atom has certain definite stable states in which it can exist, and each possible state has definite total energy. These are called the stationary states of the atom.
  - This contrary to the predictions of electromagnetic theory.
- (ii) Bohr's second postulate : The electron revolves around the nucleus only in those orbits for which the angular momentum is in integral multiple of $\frac{h}{2\pi}$.
  - Where, h is Planck's constant

    $h = 6.625 \times 10^{-34}$ J s.

    $L = \frac{nh}{2\pi}$ Where, $n = 1, 2, 3....$
- (iii) Bohr's third postulate : An electron makes a transition from one of its specified non-radiating orbits to another of lower energy. When it does so, a photon is emitted having energy equal to the energy difference between the initial and final states.
  - The frequency of the emitted photon is then given by

    $h\nu = E_i - E_f$

    Where E_i and E_f are the energies of the initial and final states and $E_i > E_f$.
- From Bohr's second postulate, the formula for the radius of n^{th} orbit for hydrogen atom is.

$$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2} \quad ... (1)$$

- The total energy of the electron in the stationary states of the hydrogen atom is

$$E_n = -\frac{1}{8\pi\varepsilon_0} \frac{e^2}{r_n} \quad ... (2)$$

- Using equation (1) and equation (2)

$$E_n = -\frac{1}{8\pi\varepsilon_0} \frac{e^2}{\left(\frac{n^2 h^2 \varepsilon_0}{\pi m e^2}\right)}$$

$$\therefore E_n = -\frac{me^4}{8\varepsilon_0^2 n^2 h^2}$$

➥ Substituting $m = 9.1 \times 10^{-31}$ kg

$e = 1.6 \times 10^{-19}$ C

$\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$

$h = 6.625 \times 10^{-34}$ Js

➥ Simplifying equation,

$$E_n = -\frac{2.18 \times 10^{-18}}{n^2} \text{ J}$$

➥ Atomic energies are often expressed in electron volts (eV).

$$\therefore E_n = -\frac{2.18 \times 10^{-18}}{n^2 \times 1.6 \times 10^{-19}} \text{ eV}$$

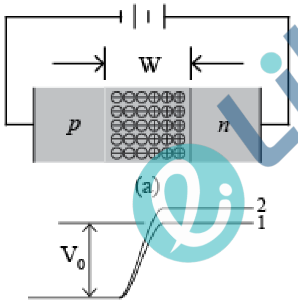
$$\therefore E_n = -\frac{13.6}{n^2} \text{ eV}$$

➥ The negative sign of the total energy of an electron moving in an orbit means that the electron is bound with the nucleus.

➥ Thus, energy will be required to remove the electron from the hydrogen atom to a distance infinitely far away from its nucleus.

27.

➥ When an external voltage (V) is applied across the diode such that n-side is positive and p-side is negative, it is said to be reverse biased.



(b)

➥ Here the applied voltage is between the two ends of the depletion region. The direction of applied voltage is same as the direction of the barrier potential.

➥ As a result, the barrier height increases and the depletion region widens due to the change in the electric field. (fig. (b)) The effective barrier height under reverse bias is (V_0 + V).

➥ This suppresses the flow of electrons from $n \rightarrow p$ and holes from $p \rightarrow n$. Thus, diffusion current, decreases enormously compared to diode under forward bias.

➥ The electric field direction of the junction is such that if electrons on p-side or holes on n-side in their random motion come close to the junction, they will be swept to its majority zone.

➥ This drift of carriers gives rise to current. The drift current is of the order of few μA. This is quite low because it is due to the motion of carriers from their minority side to their majority side across the junction.

- The diode reverse current is not very much dependent on the applied voltage. Even a small voltage is sufficient to sweep the minority carriers from one side of the junction to the other side of the junction. The current is not limited by the magnitude of the applied voltage but is limited due to the concentration of the majority carrier on either side of the junction.
- The current under reverse bias is essentially voltage independent up to a critical reverse bias voltage, known as breakdown voltage (V_{br}).
- When $V = V_{br}$, the diode reverse current increases sharply. Even a slight increase in the bias voltage causes large charge in the current.
- If the reverse current is not limited by an external circuit below the rated value (specified by the manufacturer) the p - n junction will get destroyed. Once it exceeds the rated value, the diode gets destroyed due to overheating.